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THE ASSAYER'S GUIDE.

THE

ASSAYER'S GUIDE;

OR,

PRACTICAL DIRECTIONS TO ASSAYERS, MINERS, AND SMELTERS,

FOR THE

TESTS AND ASSAYS, BY HEAT AND BY WET PROCESSES,

OF THE

ORES OF ALL THE PRINCIPAL METALS,

AND OF

GOLD AND SILVER COINS AND ALLOYS.

BY
OSCAR M. LIEBER,
LATE GEOLOGIST TO THE STATE OF MISSISSIPPI.

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PREFACE.

In presenting this little volume to the public, I trust that I am filling a void in our chemical literature. I believe there is no work in the English language on assaying which combines with practical usefulness a sufficiently popular character for those readers who have not made metallurgy, and its kindred sciences, objects of their especial study. My desire is, to offer a book which fully treats of all the subjects of assaying, and whose price will yet place it within the reach of all persons professionally interested in this important branch of knowledge.

The more compendious works on chemistry, if they allude to assaying at all, give so sparing and incidental remarks, that they do not throw any light upon it for technical purposes, as indeed it does not fall within their province to do.

The immense mineral wealth of the United States, to which the discoveries in California have so largely added, makes this art a very desirable acquirement for every one engaged in any business connected with the metals; and it would appear indispensable to those desirous of deriving the greatest advantage from a residence in that promising and alluring part of our country.

Although these pages principally treat of the processes by heat, I have thought it proper to describe also some wet processes, either where they serve as methods to rectify the former, or where no others exist; as, for instance, is the case with platinum. For the coins, I have selected those employed at mints, and which are therefore generally considered the most serviceable for the analysis of those alloys.

I feel induced here to recommend at least a partial study of blowpipe assaying, to those who may wish to make use of the instructions given in this treatise. This infant branch of chemistry was first created, I may say, in Sweden by Cromsted, and established more firmly by Gahn and Berzelius, both his countrymen; and has of late been made by Plattner a method even for quantitatively ascertaining the contents of most minerals.

The requisite blowpipe utensils for the mere detection of the principal components of ores are so few, can so easily be commanded, and may be so readily carried about one's person, that, at least for the purpose of a prior test, it is very advisable to possess some knowledge of their application, which can be acquired with great facility.

I beg to refer those readers who may be desirous of pursuing the subject more scientifically, in particular to two works of merit, neither of which is written in our language. The one is the Traité des Essais par la Voie séche, by Berthier, Paris, 1834; the other is in German,—Instructions on Assaying, for Miners and Smelters, by

Bodeman, Clausthal, 1845. The last mentioned work has been of much use to me in writing this volume.

I cannot conclude these brief remarks without seizing upon the opportunity of acknowledging the liberality of a distinguished officer at Freiberg in Saxony, Mr. Fritsche, chief assayer of that mining district. I have made frequent use of his notes and hints, given me while I had the advantage of a personal intercourse with him.

O. M. L.

COLUMBIA, S. C., 10*th April*, 1851.

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EXPLANATION OF TECHNICAL AND SCIENTIFIC TERMS USED.

Alkaline, containing an alkali, viz. potash, soda, or ammonia.

Ammoniacal, containing ammonia or hartshorn.

Assays by Heat, or processes by the sole means of fire.

Black flux. See Copper Assays.

Carats fine, a term used in designating the value of gold alloys.

Carbonate, applied to oxides, where carbonic acid is united with them.

Chlorates are combinations of muriatic acid (or table salt) with metals, &c. (bases.)

Chlorides are combinations of chlorine with metals, &c.

Crucible. See Utensils, &c.

Cupel. See Utensils, &c.

Fluxes, ingredients added to produce slags.

Fuming nitric acid, the strongest kind, emitting red vapours.

Galena, a lead ore.

Hygroscopic water, the moisture bodies attract from the atmosphere.

Muffle. See Utensils, &c.

Oil-baths, heated oil, to warm solutions, &c.

Oxidation, the combining with oxygen (rusting, &c.)

Peroxide, the oxide containing the greatest amount of oxygen.

Phosphates, combinations of phosphoric acid with metals, earths, (earthy,) &c.

Precipitation, the production of insoluble compositions, &c. in wet processes.

Protoxide, containing the least amount of oxygen.

Quartation. See Gold Assays.

Sand-bath, heated sand, to warm solutions, &c.

Sulphates, combined with sulphuric acid.

Sulphurets, combined with sulphur.

Test-glass, a glass tube closed at one end for chemical purposes.

Water-bath, heated water to warm solutions at 212° Fahrenheit.

Water of crystallization, the water contained in crystals, and by evaporating which, they crumble.

Wet processes are those in which acids and solutions are used, and where fire is never directly employed.

White flux. See Copper Assay.

THE

ASSAYER'S GUIDE.

INTRODUCTION.

ASSAYING is the science which treats of the various methods of ascertaining the amount of one or of several ingredients of a chemical compound, such as an ore or alloy, but is solely intended for practical purposes. For this reason one of its main objects is to be able to attain to a very great accuracy with the smallest and cheapest means, and in the shortest possible time. In this it is contradistinguished from inorganic analytical chemistry, properly so called. The aim of the latter is to ascertain all the different composing elements of an inorganic compound, and also the exact amount of each, and for this reason the chemist should never be deterred by a great waste of time and money, if an accurate result should require extravagant means. As assaying is only an aid to technical operations, and these never can extract the whole amount of a metal or other component part contained in a composition, (be the latter a natural or artificial one,) with true chemical precision, it is self-evident that much time and labour would be unnecessarily lost, if the same attention were devoted to it as would be requisite in an analysis. This, however, also shows that it is utterly inadequate for purely scientific ends.

Assaying was the earliest known branch of chemistry, and in fact that one which afterward, through the medium of the various investigations of alchemy, drew attention to theoretical chemistry, and thus founded that science.

The art of assaying is so ancient, and it has so constantly and imperceptibly received new additions and perfections, that its origin is entirely unknown. Agricola of Saxony, who lived in the earliest half of the sixteenth century, was the first to collect the facts and write on this subject, (G. Agricola de Re Metallica, libr. XII. Basil, 1546.) Since then the manifold discoveries of more enlightened periods have vastly enlarged and developed this branch of study.

It is not by any means always necessary that the same measures be employed for these tests as are used in the separation of the single constituent from the rest of the compound in large quantities; as, for instance, in the processes of smelting and amalgamation, although, if convenient, it is very advisable, as it facilitates the metallurgist in the detection of the best fluxes and admixtures to be added to his peculiar ores.

The assayer should be guided in his operations by chemistry, and the study of the latter, particularly as far as regards the principal and more common substances, should never be omitted. In other respects, all that can be recommended to one who desires to perfect himself in assaying, is the most scrupulous cleanliness, order, and precision as regards his assays and implements, and the most unwearying adroitness and attention in performing the manipulations required by his science.

I.

Description of the Implements and Utensils used in the course of Assays by Heat.

AMONG the articles necessary for an assayer's office, of course the first that requires a description is the furnace. For most purposes the *muffle* furnace suffices, and it is the only one used for gold, silver, and copper ores; but for iron, lead, &c. we require another, though much simpler one. I shall first describe the *muffle* furnace, (Plate I. figs. 1, 2, and 3.) The characteristic part, the one from which this furnace derives its name, is the muffle, illustrated on the same plate, in figs. 7 and 8. Both these diagrams give a perspective view, the first a semilateral, the second one from in front. They can be procured in most of our larger cities, and are manufactured in great quantity in Hessia, of a very firm and fire-proof siliceous clay, the same material as that used for the well-known Hessian crucibles, (Plate II. fig 5.) The one from which the drawing was taken in Plate I. measures eight inches across the bottom from mouth to back outside, and four inches down the back. The holes opening upwards towards the interior measure each an inch and a half lengthways, but their number of course varies according to the size of the muffle, which again should depend on the quantity of assays expected to be performed at once. The back and the mouth of the muffle are equal in size.

The muffle furnace is exhibited from in front in fig. 1, in a lateral section in fig. 3, and in a transverse perpendicular section in fig. 2. A scale, showing the proportionate dimensions in English feet, is attached, to facilitate the use of the drawings in building a furnace; for though very small, they have been made with much care, and, with the little sketches attached, are fully capable of being employed to that effect. As will be seen from the first figure, the line A B is seven feet long, while the external width of the furnace, C D, is two feet nine inches. The furnace consists of three chief parts, the chimney, *r*, in figs. 2 and 3, (which need only be 3½ feet high if it enters the chief chimney of the laboratory, which should then measure at least 9—12 feet,) the part above C D, in fig. 1, containing the muffle, and the part below that, the grate, ashes box, &c. &c. In fig. 1 we see immediately below the chimney a representation of bricks, (*firebricks*, for all in immediate contact with the heat should be of this kind; the external ones are common burnt bricks.) These, though fastened in tight, are placed so that they can be taken out, to put in a new muffle, or make other repairs when necessary. In this brickwork we have two openings, *d* and *a*. The former is only a small aperture, for inserting pieces of sheet iron, upon which to dry the cupels. It is, however, not immediately necessary, and, if present, is always closed with a tight brick when the muffle is in use. *a* is the opening of the muffle, which can be closed by a piece of fire-proof brick represented in fig. 4, having an iron piece protruding on the exterior, with a narrow opening, into which fits the handle fig. 5, which we apply on removing it. To the right and a little below the muffle is a loose brick, *e*, to be taken out whenever it becomes necessary to remove the fire-proof clay bar, *o*, which holds the muffle, (vid. fig. 2.) As seen in fig. 3, this bar as well as the three others shown in the little sketch affixed to fig. 2, and of which the centre one is a little the longest, are slightly inclined, thus elevating the back of the muffle an inch above the front, and giving a better circulation of heat, as should be the case where stone-coal or cokes are used. In burning charcoal it may be horizontal, although this inclination has another advantage, inasmuch as it enables us to clean out the muffle easier, should a cupel upset, the contents running forward. The three fireclay bars, *s s s*, are loose, while *o* is inlaid on one side, and on the other fastened in with a loose piece of brick and an iron wedge, which can be removed, as already remarked, through *e*. On inserting the bars and muffle, the parts where they meet, and where the former touch the other bricks, should be powdered over with bone-ashes, to prevent a possible adhesion from the intense heat. Small cracks in the muffle should be mended with coarsely powdered burnt clay. *p*, in fig. 2, is the open space left round the muffle about an inch and a half wide, and into which the opening *d* in figs. 1 and 3 leads. Immediately below C D we have the door *b* exhibited in all three figures. It is for the introduction of fuel, and is just above the grate, *x x*, in figs. 2 and 3, which consists of six iron bars placed in the same inclination as the muffle. The door *f*, fig. 1, is of iron, with an inside coating of fire-clay, an inch and a quarter thick, kept in place by iron rivets, thus protecting the assayer from the radiating heat of the iron, which would otherwise soon be white-hot. Below the grate stretches the chamber *q*, in figs. 2 and 3, both for draught and for the cinders. The plane at the bottom of this is inclined like the grate and muffle, and has the opening *c* to take out the ashes. To introduce a regular and sufficient quantity of atmospheric air, the channel *k* has to be constructed, which enters *q* at *h*, and passing under the floor of the laboratory opens outside at *i*, fig. 3: *l* is a small piece of sheet iron, by pulling out or pushing in which, we open or close the passage *k* at pleasure, and accordingly as we require a great influx of air or not, for a high or low temperature. The little figure annexed to fig. 1, shows the construction of the little opening and slide in the lower door. It is exactly as with a common iron stove, γ being the hole, while the slide $\alpha\beta$ can be closed over it by means of the handle, or removed, as may be desirable for different degrees of ventilation. This furnace is of the kind proposed by Professor Plattner for the Freiberg assay office for the use of stone-coal and cokes, and where it has been employed to great advantage, as regards economy and practicability in general.

Having thus pretty minutely given a description of the muffle furnace, as it can best be constructed when not required to be movable, I shall proceed to the furnace for tests of iron ores, lead ores, &c., also in a shape not intended to be moved, as represented by a lateral section in fig. 6, Plate I. Those parts in immediate contact with the heat should be constructed of fire-proof bricks, which ought to reach some distance up the chimney. The main body of the furnace B and A is either square or round, and twelve inches in diameter. The back is about three feet nine inches high, while the front measures slightly less, as the top has a little slant, merely for convenience in easier being able to get at the bottom. A is the part where the ashes collect, with a door at H having one or several openings, as is represented in the door *g*, in fig. 1, for the sake of regulating the ventilation. If this furnace is to be used for iron assays, in which case a very intense heat is requisite, a similar channel as illustrated in K, fig. 3, should be attached, the longer the better, and, if possible, opening into some cool place, e. g. a cellar, thus creating a stronger current of air, and consequently a better ventilation. Above A are the bars forming the grate F G, which ought to vary in distance from one another according as we use charcoal or stone-coal and cokes, in the former case being closer to one another. B is the part in which the crucibles are placed, as well as the fuel, and which has one opening for the introduction of the same with the cover E, suspended, when open, by a chain, but which is shut when the furnace is in use. This cover is commonly of iron, covered with fireproof clay.

C is the channel leading off to the chimney D, which may vary in width from one half to one quarter the width of B. For assays of lead and copper it is not necessary to have the chimney very high, as no very severe draught is required; but for iron assays it should be about thirty feet. In the assay office in Clausthal it measures forty-eight feet. In this case, of course, if there is also a muffle furnace on the same hearth, it is best to conduct the chimneys of both into one large one. On placing the crucibles in this furnace—twelve have room in it at once—a piece of firebrick, K in the drawing, is first placed on the grate, which, to avoid adhesion of the crucibles, may be powdered with bone-ashes. This brick is employed to have the crucibles more in the focus of heat, by elevating them above the coal around it, and also—clay being a bad conductor—to keep them from immediate contact with the cold blast. The fuel should never be heaped above I, the mouth of the channel C, and large coals should be placed below, to keep the grate from choking. If several crucibles are used at once, they ought to stand sufficiently apart to admit coals between them, as they otherwise might melt partially in the course of the process, and form one compact mass.

On the foregoing pages I have furnished descriptions and measurements of furnaces, which, as I have already remarked, though easily constructed, are not portable; and it is proper that, before closing this chapter, I should devote a few lines to the mention of those, which, from their being movable, and thus obviating the difficulty and inconvenience of constructing one, might, in many cases, be preferred, although their smaller dimensions, as a matter of course, make it more difficult to perform good assays, and impossible to attend to many at a time. Among these we have both muffle furnaces, and wind furnaces such as last described. They are made of sheet iron, strongly fastened with iron hoops and coated inside with fireclay, (see also Chap. XVI.) They can generally be procured at all larger stores of chemical apparatus. Luhme & Co. of Berlin, who have one of the largest assortments of such articles in Europe, and for comparatively cheap prices, furnish a kind which may be used for both purposes, for 50 Prussian dollars, about $35.00 our money. There is another kind of portable furnace with an iron muffle, but which can only be applied to silver and gold assays, (coin,) which may suffice for the wants of many, and which is more durable than the others. After having thus given a description of the furnaces used in the course of the experiments elucidated in the following pages, I shall venture to call the reader's attention to other instruments used in the assays of ores. Among these, probably, the balance will appear most conspicuous. There ought to be two in use, one very accurate, the other less so, for more common purposes, as weighing off the ingredients or admixtures, such as pure lead, borax, &c. The other one should be made with great care, and only used to weigh off the small buttons of gold and silver procured. Accurate analytical scales are required; and should it be more practicable to possess them in a small and compact shape, I would propose the blowpipe balance suggested by Professor Plattner of Freiberg, and made in that place by a very careful workman of such instruments, Mr. Beschorner, who furnishes them for all the students of the mining academy there. This balance can be procured most simply from Luhme & Co. in Berlin,* who are in constant connection with the United States, and furnish them handsomely got up, with an elegant mahogany box, containing weights of platinum down to one-tenth of a milligramme, or 0.003543402 grs. Troy, for about $16. The same firm can also provide common balances, from Professor Wackenrode's (of Jena) description, for $4 or $5. It would be very advisable to have a medium balance to employ with the baser metals, marking a milligramme with about twenty-five grammes weight, costing about $13 or $14. It will be unnecessary to give a drawing of these balances, and I believe the short description is sufficient to define the accuracy and qualities required. I may add, however, that it is highly advisable to have wires of platinum used everywhere in the more exact ones, since then an unequal extension or contraction of the silk cords, otherwise commonly used, and which necessarily cause variations, is avoided.

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* J. F. Luhme & Co., 51 Kurstrasse, Berlin.

We must now cast a glance at the

smaller and less costly utensils, but all of which are necessary for the accomplishment of the operations to be performed as directed in the following pages. I allude to the crucibles, *cupels* or cups, and tongs, &c., illustrated in Plate II. The former, figs. 1, 2, 3, 4 and 5, are all of their natural size in the drawings. Figs. 1, 3, and 4, should be made from accurate descriptions by a potter, of a pure clay, containing as little silica mechanically combined as possible, since its presence prevents the vessels from being sufficiently porous to allow the oxidizing metals to enter, which would, as will hereafter be seen, become a great drawback to the assay. Some hundreds must always be kept on hand, for they can only be used once, as the lead, almost always present, glazes them immediately.

Fig. 1 represents a *cupel* used in the operation technically termed *cupellation* of the gold and silver ores: *a* shows it from above, *b* from the side. The concave inner surface should not be too shallow, thus letting the contents run over; nor, on the other hand, too deep, in which case too small a surface would be exposed to the oxidizing power of the heat. The line given in *b* shows the proper inclination within.

Fig. 2 is a truncated cone, with a very slightly concave surface at the wider extremity or top. It is made in great part of bone-ashes, being among the most porous substances that can stand a high temperature. I give here a recipe for their preparation, furnished me by Mr. Fritsche. It shows the relative quantity of the ingredients as used for these cupels at his office, where they are made by the laboratory servant in wooden moulds, using a rod, shaped like a pestle, to make the hollow at the top. The mass consists of 4 parts of wood-ashes previously freed of the potash by filtration, 1 part of lime, and 1 part of bone-ash.

Fig. 3 shows a flat, shallow crucible, made of the same pure clay as that represented in fig. 1: *a* is the cup as seen from above, while *b* gives a lateral view, showing also the curve of the inner surface. This vessel is used in the assay of copper, as well as fig. 4. Fig. 3 is termed in German "*Kupfer Garscherbe*," from the fact that with its use the copper assay is finished.

Fig. 4 is a high crucible, as mentioned above, used for copper and lead. It is made of the same material as the former. The reason of its having so great a height compared with its width, and otherwise so peculiar a form, is to concentrate all the heat round about the bottom of the interior. In some places, in lieu of better, the Hessian crucible (fig. 5) is used; but No. 4 is much better adapted, from the height of the foot-piece, which also protects the contents from the cooling influence of the iron bars on which they are placed, and from a too direct contact with the cold draught. Some assayers use an extra cover for this crucible, a very superfluous addition, since the bottoms of the old crucibles answer admirably as covers to the new. As mentioned before, these also are useless after once having been employed, and before throwing them away it is therefore well first to break off the feet.

Fig. 5 gives a drawing of a Hessian crucible, which is used chiefly in the assays of iron ores. These are imported into the United States, and can be procured in almost every crockery store. Their dimensions are very different, and so contrived that one fits into the next in size, being in sets of about a dozen. They are commonly triangular above, and round below, as shown in the figure; but sometimes they are made round above and below, and where these can be had, they should be preferred. If they cannot be procured, similar crucibles of pure clay may be substituted, and in fact they are sometimes considered preferable. The latter are then commonly made with a foot-piece, somewhat as in fig. 4, though not quite so strongly separated from the main bulk of the vessel. These or the Hessian crucibles, as will be seen hereafter, should be kept constantly on hand thickly coated with charcoal. They are prepared in this manner. Charcoal of any oak-wood, except red-oak, which contains much oxide of iron, is the best on account of its density. It should be pulverized with the utmost care, since a coarse powder will never furnish a consistent mass. To this we carefully add water until we procure a tough paste or dough, and with this fill the crucible very tightly, always ramming down every new portion introduced, with a pestle or piece of wood. When the whole interior is filled up, we cut out a hole in the middle with a penknife, leaving a margin of about half an inch at least, below and all round. (See Assay of Iron Ores.)

Fig. 6 furnishes a sketch of an implement, which, though not immediately necessary, will be found extremely useful, inasmuch as it tends to keep up order and accuracy, great requisites for an able assayer. As will be seen from the different views *a* and *b*, it consists simply of a piece of sheet-iron, having a wooden handle and several semi-circular cavities, the number of which may vary according to the number of assays expected to be performed at once. If a large muffle is used in the furnace, it is well also to have this large; and, in fact, I would suggest having the number of holes in each row equal to the number of cupels, of the sort illustrated in fig. 1, that can, without collision, be placed across the muffle from side to side. (See Silver and Gold Ores.) This pan, or whatever we may otherwise term it, is used to cool the buttons of metal and their surrounding slag after having oxidized part of the lead, &c., and separated the gangue-rock, as is the case with silver and gold (q. v.) The holes should be 1½ inch wide and ½ inch deep.

Figs. 7 and 8 represent two different kinds of tongs. Fig. 7 is only shown in a lateral view, since its characteristics are thus exhibited, while fig. 8 is sketched from above. They are both very necessary in the progress of our investigations. The first is shaped like common fire-tongs, only that the ends, instead of widening into a flat circular lobe, are bent downward like a poker, thus enabling us to handle the crucibles with great care. The second tongs has each piece ending in a semicircle, the diameter of which circle, when united, should be so that it may exactly embrace the lower part of fig. 1. It is used to place those cupels into the muffle, as we are thereby prevented from touching the contents. In using this latter instrument great caution should be taken not to upset the cupels. Let me first remark, that on introducing the cupels into the muffle, we always commence with No. 1, i. e. first assay on hand, behind on the left. It may seem a very superfluous precaution to dwell thus long on so simple a manipulation as the one I am now describing; but I know from experience, how many failures carelessness in this procedure occasions to the uninitiated. Let us now suppose, that we have the crucible, fig. 1, filled with the powdered mineral to be tested, and the other additions, such as lead or borax. Grasping the cupel firmly at the bottom, we lift it up high, so that, when pushed into the mouth of the muffle, it is a good deal above its floor, and cannot knock against it. As soon as it is within the muffle, without leaving hold of it, and keeping it up high, we hold the side of the tongs up against the side of the muffle to steady them, then run them along quietly though not too slowly, for that only causes the hand to tremble, until the crucible is just above the spot where we intend to place it, (when once down it should never be moved,) and then slowly lower it, not letting go till it stands secure.

These tongs should be made light enough conveniently to handle them with one hand. The handles are made of some good firm wood, though No. 8 is generally held lower down than the handles, and, I may add, never so that the end of the tongs, the handle, passes under the arm, but exactly as the savages hold their darts when about to hurl them. It may seem awkward at first, and yet I know many accidents, as regards the assays, having occurred from not attending to it. The length of the tongs ought to be about three feet. It may be well to supply oneself with a third pair, with straight and rather pointed ends.

II.

Assay of Silver Ores by Heat—Cupellation.

SILVER occurs in nature chiefly in lead ores, (galena,) and native, as in the Lake Superior copper mines, or less commonly as chloride of silver, as is the case in the extensive mines of Chili. The following directions, however, refer equally to the assays of all.

As with all minerals to be investigated by these methods, the ore must previously be reduced to the finest possible powder, for which purpose, where many assays are made, a large iron bowl is used as a mortar, the pestle having a wooden handle attached at right angles to the iron part, enabling us thus to employ a much greater force than if it were straight, as commonly is the case. The usual shape of a mortar, used in kitchens is not so good, for its depth prevents its being cleaned sufficiently to insure accuracy. In lieu of the former, and when small quantities only are desired to be pulverized, an agate mortar may suffice. Of the ore we weigh off one part,—about 3 grammes, equal to 46 grs. Troy, (say 50 grs.) is a good standard weight,—and mix it with ten parts by weight of pure lead, and from one-tenth to one-fifth part of borax, in the manner described below.

The lead is added to extract all impurities, such as copper, nickel, &c., and in cases where these occur in great abundance, should be used in the proportions even up to fifteen and twenty parts, though it is always injurious, and tends to create a loss, to add too much.

To the rules for testing the quality of alloys of silver and copper, will be found subjoined a table by Erker, to regulate this.

The lead of commerce contains many impurities, in the shape of other metals, which, since silver always is among them, is very injurious to our assays, and it is therefore necessary to obtain a purer article. At silver furnaces lead is produced as an extra product, sufficiently pure for our purposes. That, for instance, thus procured from the smelting works at Freiberg in Saxony, and used there by the assayers, contains, to 6:40000 parts of lead, from 0.00001 to 0.000015 parts of silver, too slight an impurity to affect the result of the assay. If so situated as not to be able to get it in this manner, the best way is to reduce it by a galvanic process from acetate of lead. This, the sugar of lead of commerce, we can readily dissolve in lukewarm water, after which we should filter off the solution, and introduce a rod of zinc, by which process all the lead is reduced and collected round that metal. After some time remove it, and continue in this manner until all the lead is precipitated. It is then to be repeatedly washed with care to remove the acid, and afterward dried between blotting paper. If not in a sufficiently pulverized shape, it need only be shaken a little in a towel and finally sieved. A spoon containing a given amount—five parts, equal to 250 grs., is convenient—is used to measure the quantity for each assay, thus avoiding the tedium of weighing each time, a matter of considerable consequence in an assaying office, where frequently hundreds of assays are made in a day.

The vessel into which the mineral, together with the lead and borax, is placed, to be introduced into the muffle of the furnace, is represented in fig. 1, Plate II. (See the description given a few pages back.) We first put one-half of the lead to be used in it, and on the top the silver ore, mixing the two with great care, not to spill the least particle, and afterward cover it with the rest of the lead, and sprinkle the borax over the whole. The latter is used to facilitate the melting of the lead, and to produce a good slag. When much tin, zinc, or lime is present in the ore, the borax should be increased in quantity up to the largest amount before mentioned.

If we desire to test ores containing very little silica, and our crucibles are not as perfect as we might wish them to be, it is very advisable to make use of some quartz or glass-powder, to be added immediately, or, better still, when the slag is forming, and the process of calcining is thus at an end.

We should, for the sake of economy with the fuel, make several assays at once, and always five or six of each ore, afterward taking the average, and thus regulating our own labour.

After previously firing the furnace, and bringing the muffle to a regular and constant red-heat, we may introduce the crucibles. To quicken the melting of the lead, we place some pieces of well-dried charcoal, which should always be kept on hand, in front of the crucibles. Vapours will be observed to be emitted, caused by the discharge of volatile substances. The door of the muffle, previously closed, should be kept perfectly open as soon as the operation of calcining or roasting the ore has properly commenced, to admit fresh air, and prevent the heat from increasing too much.

This process generally lasts about twenty minutes, after which, by introducing fresh coals into the muffle and again closing the door, we raise the heat, and continue it sufficiently long to let the slags collect and flow easily, so as to make a crust round the white-hot metal. When not employing a sufficiently high temperature, the slag will remain thick or tough, and retain the metallic alloy of silver and lead in small particles disseminated throughout the mass.

From the circular portion of argentiferous lead, which appears to be in a constant rotary motion in the centre of the slag, vapours of lead rise incessantly. The time that should be occupied by this process of melting varies much according to the character and quality of the ore, which sometimes, though rarely, may even require something more than half an hour. Generally much less time is wanted with a good fire, and the assayer can always see at what time the encircling slag has been properly separated from the metal, and even with very little practice is enabled to regulate it. We now again open the muffle, and by oxidizing some more lead during the space of ten minutes, cover the metal entirely, and after that, once more apply a strong heat for a few minutes to make the slags flow easy, and then taking out the crucibles, pour the whole contents into the different hollows of the iron plate, illustrated by fig. 6, Plate II. This should be done very quickly, for otherwise the lead will not collect in one button, but be distributed in small particles all over the molten slag as above. A little practice will soon accustom any one to all these operations.

On cooling, with a stroke or two of the hammer we separate the slags from the metallic buttons, and with a few more easily shape the latter into cubes as regular as possible.

The crucibles shown in fig. 2, Plate II. come into use at this part of the assay. If well made and dried, they should be very porous, and so friable as to be crushed between the fingers with ease.

In these cupels we expose the metal cubes to a moderate red-heat, which we are enabled to regulate by inserting cold pieces of pottery—old crucibles will be found very serviceable—and leaving the furnace open. The rising vapours are from the lead, and continue until that peculiar bright flash of light is observed, termed *silberblick*, (silvergleam,) in German mining and smelting technology, and from which we know that the silver is pure. The utmost attention should be paid to this part of the assay, to ascertain the moment when this occurs. The coolers are then carefully removed, the aperture closed, and the most intense heat possible kept up for a few moments. To do this well is, I may say, the *chef d'œuvre* of an assayer, and on it depends, in a great measure, the accuracy of the assay; for the silver, when pure, requires a much greater heat to bring it to the melting point than when it contains even a very small admixture of lead; and for this reason, if we do not instantly elevate the temperature when the ceasing of the rainbow colours and the bright light of the globule of pure silver inform us that all the lead has left,—then the silver would cool suddenly, and, of course, quicker at the surface than in the interior or at the bottom, and by this subitaneous contraction cause a spattering motion of the yet unconsolidated particles, and be productive of great loss to the assay.

There is an old adage current among German smelters and assayers,—probably known to all who may have had the advantage of studying this art in that country, where it has been brought to such perfection,—which, since it is many centuries old, shows how long it has been regarded as the great aim, in this mode of testing silver ores, to keep up a moderate temperature as long as any lead is left, and to apply intense heat as soon as all has departed. I insert them here:

> "Kühl getrieben, heisser Blick
> Ist des Probierer's Meisterstück."

In English it would be: To evaporate coolly and to use heat when pure, is the masterpiece of an assayer.

When the buttons of pure silver have cooled, we grasp them firmly with a pair of pincers, tight enough to compress the sides, thus exposing the bottom more, and with a wire brush remove the adhering particles of litharge, and dust of the cupel. Turning them half round so as to make the base a square, we repeat the operation, and then weigh, but only when quite cold, since otherwise the heat, by increasing the bulk, might tend to create a variation.

The silver produced in this manner, it should be remarked, is not perfectly pure, chemically speaking, but the slight impurities are too insignificant to deserve any attention from an assayer, who has nothing but technical purposes in view, though they might require it from a scientific chemist; and for this latter reason, I have thought proper in the third chapter to suggest a method to ascertain the exact amount of silver in this button, should it be deemed necessary, though, I must add, that such precision can only be required at mints, if the investigations are not conducted for science' sake, in which case, the wet process would, of course, be preferred from the beginning.

Besides this, small inaccuracies in the shape of losses, as has already been remarked, cannot be averted, even though the assay be performed with the greatest care, as the evaporating, or rather oxidizing lead probably carries off small particles of silver, particularly when too much heat is used during that process. It is impossible to give any perfect rules how to obviate such faults, since so much depends on the care and attention paid, as well as on the acquired practice and innate practical skill of the assayer; yet, pre-supposing all this as perfect, the Parisian mint has established a table to regulate their assays, which will be found on pages 52 and 53. From this it is seen that the different losses with different quantities of silver vary considerably, nor is the loss a per-centage, being greatest where the original or true amount of silver in the ore or alloy is seven hundred.

This table should always be referred to, as it enables us to calculate the true amount of silver, and to rectify those unavoidable faults which may be occasioned by the lead carrying off portions of the silver entirely, or else drawing them along with it into the pores of the crucible.

III.

A Table to rectify the Loss incurred during the Silver Assay.

Real amount of silver.	Amount of silver found by the assay.	Loss during the process.
1000	998·97	1·03
975	973·24	1·76
950	947·50	2·50
925	921·75	3·25
900	896·00	4·00
875	870·93	4·07
850	845·85	4·15
825	820·78	4·22
800	795·70	4·30
775	770·59	4·41
750	745·48	4·52
725	720·36	4·64
700	695·25	4·75
675	670·27	4·73
650	645·29	4·71
625	620·30	4·70
600	595·32	4·68
575	570·32	4·68

Real amount of silver.	Amount of silver found by the assay.	Loss during the process.
550	545·32	4·68
525	520·32	4·68
500	495·32	4·68
475	470·50	4·50
450	445·69	4·31
425	420·87	4·13
400	396·05	3·95
375	371·39	3·61
350	346·73	3·27
325	322·06	2·94
300	297·40	2·60
275	272·42	2·58
250	247·44	2·56
225	222·45	2·55
200	197·47	2·53
175	172·88	2·12
150	148·30	1·70
125	123·71	1·29
100	99·12	0·88
75	74·34	0·66
50	49·56	0·44
25	24·78	0·22

IV.

Gay-Lussac's Process for assaying Silver Alloys.

THIS *modus operandi* is one which, from its very simplicity and shortness, almost necessarily insures success, but it is only intended for alloys, such as coins, and can, therefore, if applied to ores, only be used to ascertain the real amount of silver in the button produced in the last assay, which, as already observed, contains a very minute amount of spurious metals in an alloyed state.

It was proposed by Gay-Lussac, and from the indubitableness of its results, has since been introduced in France, and most parts of Germany, to regulate the assays of the mint.

They dissolve a given weight of the

alloy in nitric acid, and then find a solution of common salt—of which, a large assortment of different known degrees of strength is constantly kept on hand in bottles—sufficiently strong to precipitate all the silver as chloride of silver, when used in a certain established quantity. In this manner, the amount of silver is found by the quantity of salt used. (Gay-Lussac on Assays of Silver, q. v.)

V.

Assay of Gold Ores by Heat.

Those properties of silver, which enable us to assay its ores by the process of cupellation, are so equally characteristic of gold and its ores, that, were I to dwell more at length on this first part of the operation, it would be a mere repetition of what has been said under the head of Silver, and therefore I shall only refer the reader to the remarks given above.

When, however, that process is completed, and when therefore with silver we would have procured the final result, the real gold assay only commences, for gold, though always native, contains silver, platinum, &c.

I must remark that, since gold ores are almost invariably excessively poor, compared with those of other metals, we should arrange our assays accordingly, and commence with a larger amount of ore than is necessary in other cases. For this purpose it is common to begin with six different parts of ore of 50 grs. each, which, after being mixed with lead and borax as with silver, are committed to the muffle in as many separate crucibles. The products are then melted up into two buttons, in two different cupels of the same kind, and these again in the process of extracting the lead are concentrated into one. Of course, when the assay is finished we are obliged to divide the produce by six to ascertain the per-centage amount of gold in the specimen under examination.

After having proceeded thus far, it is necessary to procure some perfectly pure silver, for which we have the following methods: first, by producing chloride of silver, which is done by precipitating the silver from the nitric acid solution, with muriatic acid, and melting it in a porcelain crucible, with potash; chloride of potash and the pure silver being thus formed: or secondly by the galvanic process, the virgin metal being thus collected round a rod of zinc immersed in the acid (nitric) liquid from which, as above, the silver has been extracted by adding muriatic acid, but which precipitate must remain in the same vessel. The silver is then preserved in the shape of filings.

It is necessary to make use of this silver whenever the quantity of gold in the last produced button is more than one fourth, (hence the term *quartation*) since experience has shown that if there are not at least about three quarters the amount of silver (rarely the case with ores) in this alloy, the gold would protect the particles of silver from the action of the acid, which, as will become evident from the sequel, would prove fatal to our investigations.

Of the pure silver, two and a half times the weight of the buttons of impure gold, and about half the weight of both in pure lead, should be melted up with them in one crucible, (fig. 2, Plate II.) This single button of gold and silver alloy is to be hammered flat on a little steel anvil, and slightly curved, as this shape will allow it more easily to pass through the mouth of a little vial, in which it is now placed to be boiled with nitric acid (2 drams) of from 1 to 3 specific gravity. The vial should be round at the bottom as this is performed over a spirit-lamp. We allow the liquid to boil until the yellowish vapours of nitrous acid gas have ceased to be emitted. The gold is then pure, and requires only to be boiled a couple of times in water to remove the acid, and then to be heated to redness to evaporate the water, to enable us to weigh it, which, as with all other assays, should never be done till the metal is perfectly cold.

If a small portion of platinum be in the ore, it will be found in the nitric acid solution of silver. (See Platinum.)

The original amount of silver may be ascertained by deducting the weight of the gold from the button produced before the other pure silver was added.

VI.

Assay of Gold Ores by Amalgamation.

This method is founded on the fact, that gold unites with quicksilver to form an amalgam, for thus the alloys of mercury and other metals are termed. It is one that may answer for peculiar circumstances, though it is not accurate enough to serve as a regular dokimastic* test, since lead and silver also produce amalgams.

We require pure mercury for this purpose; and as the quicksilver of commerce generally contains some lead, we must purify it by pressing it through a piece of buckskin.

The powdered gold ore, which ought

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* A technical term, derived from the Greek verb δοκιμάζειν, to try, to test the purity of a thing.

and three-quarters of an inch in diameter, closed at the end, like a common chemical test-glass. I would suggest, if, where used, the gangue-rock or sand be always of the same kind, having a mark round the tube made with a slight scratch of the diamond, up to where a certain quantity by weight of the ore would reach. One hundred grains would not be too much, if, for instance, the rock is quartz; and it is also the most convenient amount, from the facility thus afforded in afterward calculating the per-centage. Under circumstances where we have to deal with ores in which the original rock is not always the same, it would be well to have several such tubes, to each of which its peculiar rock might be allotted; or one with differently marked lines. In this manner, one such line might indicate the part of the tube which would be filled by a hundred grains of the quartzose ore, another the portion which would be occupied by the same weight of a talcose one, and so on. The lines will vary in height as the ratio of the various specific gravities of the respective ores.

When the properly pulverized ore has been placed in the glass tube, the latter should be filled up two-thirds with water, and tightly corked; after which, by repeated shakings, the gold will be collected below. By careful decanting and continual shaking, we can remove the sand and particles of rock, and retain the gold as a matter of course, though only in its natural, alloyed state.

This method will be found to be a considerable improvement on the washing in pans. If the ore contains iron pyrites, it is best to calcine it first, though carefully, so that no gold is carried off mechanically by the gases formed.

VIII.

Assay of Gold Ores by a Wet Process.

ALTHOUGH I have tried to make it a point to introduce as few wet processes as possible into this treatise, I now venture to give directions for one which will be found very available to ascertain the true amount of gold, when the gold has been extracted in its natural state by the last-given methods. It is characterized by the ease with which it can be performed.

The residue of alloyed gold produced by washing the ore or sand should be submitted to the action of concentrated aqua regia, (consisting of from three to four parts of muriatic acid, to one of nitric,) by which all the gold is extracted. All the platinum, if that metal be present, will be precipitated as below from this liquid.

The solution should then be filtered off with the greatest care, water being afterward poured on to wash the insoluble parts, and to procure the whole of the dissolved gold. Sal-ammonia is then to be added, and if causing a precipitate, the infusion filtered again. This latter is then evaporated to dryness, and alcohol of 0·84 specific gravity repeatedly added, and after digesting poured off, until no more coloured by the dissolving chlorate of gold. Iron vitriol (copperas) in solution, if poured into it, will precipitate the pure gold as a brown powder, which may then be filtered, washed, heated to redness, and weighed.

IX.

Assay of Silver Coins, or Alloys of Silver and Copper.

As a matter of course, with these alloys it is not necessary to perform the operation, which is done with the ores, of first separating the gangue-rock. We proceed with the cupellation, as soon as by prior tests we have ascertained the probable amount of silver and copper. To know this more accurately no method exists, except a previous hasty cupellation, though to a practised assayer it is cognisable from the greater specific gravity, whiter colour, and increased malleability of the more argentiferous alloys. It is necessary previously to become acquainted with this, as the quantity of lead must be taken accordingly. By adding too much, a loss of silver is incurred, while, if too little is used, we will not be able to procure a pure silver button, as not all the copper will pass over into the litharge.

The table to regulate the requisite quantity of lead, was calculated by Erker. Still later, D'Arcet arranged another, which, though less simple, experience has shown to be no more accurate, and it is for this reason that I have subjoined the former.

32 parts of the Alloy containing		Require in parts of Lead.	Relative quantities of Copper to Lead.
Parts in Silver.	Parts in Copper.		
31	1	128	1 : 128
30	2	192	1 : 96
28	4	256	1 : 64
24–26	8–6	320	1 : 40–53
18–24	14–8	448	1 : 32–54
8–16	24–16	480	1 : 20–30
2–8	30–24	512	1 : 16–21

From this table, it is evident that the relative amount of lead should decrease as the copper increases, although the more copper the alloy contains, the more lead should be used.

The only way to pulverise a coin or oy is to file off small portions. About gramme or fifteen grains of the filings hould be carefully weighed off, wrapped (satin paper is the best, giving ashes,) to prevent small particles n being lost, and placed in the muffle ace on the cupel, fig. 2. When the er is burnt to ashes, the lead is added rding to the table. The rest of the say is exactly as with silver ores. As long as lead and copper are being oxidized, no severe heat should be employed, which is, however, done as soon as the bright flash appears.

The alloy or coin may also be treated according to Gay-Lussac's process, already described. Having thus ascertained the amount of silver, we are easily enabled to calculate that of the copper, by subtraction.

X.

Assay of Gold Coins, or Alloys containing Gold, Silver, and Copper.

BEFORE making the regular assay, it is necessary to ascertain the probable contents of the alloy, as with silver. The method commonly used is the *touchstone* or *besanite* test, the same employed by goldsmiths when purchasing coin or bullion. A dark fine-grained basalt or siliceous slate is required, and on this a line is drawn with the gold coin. Those whom business has frequently brought in contact with such alloys are generally able to judge pretty accurately by this alone, as the purer it is, the brighter the yellow, silver making it whitish, copper of a redder hue. To carry this test out farther, the mark is moistened with an acid, which, dissolving the baser metals, leaves the gold in its virgin state. This acid consists, in thousand parts, of

784 parts of pure nitric acid, of 1.340 specific gravity.
16 " " " muriatic acid, of 1.173 spec. grav.
200 " " " distilled water.
1000

As with gold ores, several assays should be made at once, to regulate one another. When some of the alloy has been filed off—too small pieces ought not to be taken, on account of their liability to be blown away—these particles should be carefully brushed, to remove the fine dust, which might otherwise only drop off after weighing, and thus cause a decided loss.

For the assays, 5 grains are used in each, and the value of the gold is afterward given in carats fine, pure gold being reckoned at 24 carats fine. In this way an alloy containing 91.666 per cent. of gold will be 22 carats fine, or in other words, it contains $\frac{22}{24}$ or $\frac{11}{12}$ of pure gold to $\frac{1}{12}$ of the alloyed metal.

After having weighed off the above quantity of the gold to be tested, three times the weight of the expected amount of gold, as ascertained by the prior investigations, are taken in pure silver. Some deem two and a half sufficient. The gold and the silver are then carefully wrapped in a piece of paper.

It is now necessary to ascertain the required quantity of pure lead, which varies according to the per-centage of copper in the coin or alloy. As this metal has a much greater affinity for gold than for silver, it is much more difficult to separate it from its alloys with the former than with the latter, and for this reason the lead used should be about twice as much as would be necessary, were we assaying a coin consisting of silver and copper. The following table is given by D'Arcet to regulate the amount to be used:—

he contents of gold in the alloy is .		The quantity of lead required is	Relative quantity of lead to the copper.
00 parts.	In carats fine.		
1.000	24.	1	0
0.900	21.6	10	100.000 to 1
0.800	19.2	16	80.000 to 1
0.700	16.8	22	73.333 to 1
0.600	14.4	24	60.000 to 1
0.500	12.0	26	52.600 to 1
0.400	9.6	34	56.666 to 1
0.300	7.2	34	48.571 to 1
0.200	4.8	34	42.500 to 1
0.100	2.4	34	37.777 to 1

As with silver assays, if too much be employed, it will produce a loss, while too little would not extract all the copper.

The lead is first placed in the cupel, (fig. 2,) and only when the process of oxidation has commenced, is the paper containing the gold and silver to be added. The rest is performed exactly as with gold ores. The button should be hammered to a very thin sheet, before being submitted to the nitric acid; and to do this well, it should be perfectly cold, as otherwise marginal cracks are often produced, which again may be productive of loss.

It may not be quite out of place here to give the contents of pure gold in carats fine, and the weight and value of the United States gold coins, as well as of those of other nations, made legal tender with us, according to the act of Congress of June, 1834. By an act of that date, the standard value of our eagles, and other gold coins in proportion, was changed; as will be seen from the subjoined table, which has been taken from the American Almanac of 1835, page 153.

Names of Coins, and Countries where minted.	Weight.		Cont. in pure Gold.	Assay.		New Value since July 31, 1834.		
	dwt.	grs.	grs.	car.	grs.	dol.	cts.	m.
United States. Eagle coined before July 31, 1834	11	6	247·5	22	—	10	66	5
Do. since then, double and shares in proportion	10	18	232	21	2¼⅘	10	—	–
Brazil. Johannes, ½ in propor.	18	—		21	8¾	17	6	4
Dobraon	34	12	759	22	—	32	70	6
Dobra	18	6	401·5	22	—	17	30	1
Moidore, ½ in proportion	6	22	152·2	22	—	6	55	7
Crusado		16¼	14·8	21	3¾	—	63	8
Colombia. Doubloon	17	9	360·5	20	3	15	53	5
England. Guinea, ½ in propor.	5	8½	118·7	22	—	5	7	5
Sovereign do	5	2½	113·1	22	—	4	83	8

Names of Coins, and Countries where minted.	Weight.		Cont. in pure Gold.	Assay.		New Value since July 31, 1834.		
	dw.	grs.	grs.	car.	grs.	dol.	cts.	m.
England. Seven Shilling Piece.	1	19	39·6	22	—	1	69	8
France. Double Louis coined before 1786	10	11	224·9	21	2	9	68	8
Louis do	5	5½	112·4	21	2	4	84	3
Double Louis coined since 1786	9	20	212·6	21	2½	9	16	2
Louis coined since 1786	4	22	106·3	21	2½	4	58	1
Double Napoleon, or 40 frs	8	7	179	21	2¼	7	70	3
Napoleon, or 20 francs	4	3½	89·7	21	2¼	3	86	6
Mexico. Doubloons, shares in proportion	17	9	360·5	20	3	15	53	5
Portugal. Dobroan	34	12	759	22		32	70	6
Dobra	18	6	401·5	22		17	30	1
Johannes	18	—				17	6	4
Moidore, ½ in proportion	6	22	152·2	21	3¾	6	55	7
Piece of 16 Testoons, or 1600 rees	2	6	49·3	22		2	12	1
Old Crusado, or 400 rees	—	15	13·6	21	3⅝	—	58	8
New do. or 480 rees	—	16¼	14·8	21	3½	—	63	7
Milree coined in 1755	—	19¾	18·1	21	3⅜	—	78	
New Dobra	17	6		22	—	16	25	3
Joannese, double in propt.	9	6½		21	3¾	8	76	3
½ do.	4	15		21	3¾	4	37	1
Piece of 12 Testoons, or 1200 rees	1	16¼		21	3⅝	1	57	4
Do. of 8 Testoons, or 800 rees.	1	4½		21	3⅝	1	12	-
Spain. Quadruple Pistole, or Doubloons, 1772, double, single, and shares in propt.	17	8½	37·2	21	2½	16	3	8
Doubloon, 1801	17	9	360·5	20	3	15	53	5
Pistole, 1801	4	8¼	90·1	20	3	3	88	4
Coronilla, Gold Dollar or Vintem, 1801	1	3	22·8	20	1½	—	98	3

XI.

Assay of Platinum Ores.

THIS metal has as yet occurred in the United States only in gold ores, and even then in the merest traces, and hence, perhaps, it would barely deserve a mention in these pages; but the great interest attached to its occurrence, as so rare a metal all over the world, and its useful application to chemical purposes, has caused me to insert some rules for its assay.

If the ore contain platinum in no larger amount than three or four per cent. of the gold, the former, as already observed in Article V. on quartation, will be entirely dissolved in the nitric acid used on account of the silver. From this solution of the two metals precipitate the silver with common salt, or muriatic acid, as chloride of silver; filter and wash until the water dropping from the funnel no longer contains any of the platinum solution. This latter evaporate to dryness, after adding sal-ammonia. Wash it with alcohol, (see Gold, art. VIII.) and heat the double chloride of platinum and ammonium to redness, thus producing a spongy mass of pure platinum.

If there be more than three or four per cent. of platinum in the gold, its presence is readily perceived, from various circumstances: thus, in evaporating the lead a higher temperature is necessary than is commonly the case, to make the metal flow and acquire a round form; secondly, the bright light cannot be observed; thirdly, the surface of the button is crystalline or rough, and when large, flat and quite irregular, besides looking dull and having a more or less grayish colour; fourthly, the nitric acid is frequently discoloured; and fifthly, the little roll of gold is not of a pure gold yellow, but rather inclining towards steel gray.

After having thus recognised a larger quantity of this metal, it becomes necessary, since copper is frequently present, to make a prior test, to ascertain, by cupellation, the amount of the alloy of gold and platinum. After that, two assays should be made; the one, to ascertain the exact conjoint per-centage of the two; the other, inquartation (pure) silver being added, to discover the amount of the gold alone. The difference of the two results gives the amount of platinum. The inquartation silver should not be more than from two and a half to three times the weight of the alloy of gold and platinum; and it is often well to add a certain, accurately weighed quantity of pure gold at the same time, so that the gold may afterward be procured in one connected sheet or piece. This ought particularly to be done, when there is as much as a third the weight of the gold in platinum, as, for instance, in the platinum grains of the Ural Mountains, which contain about 80 per cent. The button is hammered flat, and proceeded with exactly as gold ores, the platinum dissolving with the silver in nitric acid. But as it does not do so as easily as the latter, at least when in large quantities, it is necessary to repeat the process from the quartering on once or twice, using silver and lead over again. This should be done until nothing but the silver used is dissolved in the nitric acid, or, in other words, until two assays following one another have produced the same results, a thing that may not occur until the fifth time.

It should be remarked, that it is necessary to add a little more lead for cupellation, than would be done if no platinum were in the ore; and also, that just before the bright flash of light occurs during the operation of quartering, it is well to shake the cupel a little, to make the button stiffen, as soon as the last lead has entered the former, by which the platinum will be more regularly distributed in the alloy, and cannot so well collect in different unconnected lumps, unexposed afterward to the action of the acid. The platinum may then be extracted and reduced from the solution, as above.

XII.

Assay of Copper Ores—German and Hungarian Method.

This ore, if a sulphuret, as is very generally the case, should, after having been reduced to the finest possible powder, be submitted to the process of roasting, vulgarly termed calcining. For this purpose one part by weight of the ore is mixed up with one fifth of graphite, (black-lead,) which, consisting of carbon in a more condensed state than that element occurs in charcoal, is, therefore, so much the more effectual in driving off the sulphur. This mixture of the two should be exposed to an intense red-heat in the cupel, (fig. 1,) (painted over on the inside with red chalk, or Spanish red, to prevent adhesion,) for about twenty minutes, after which it is to be taken out, and stirred up with a small iron ladle to expose the unburnt parts of graphite, when it should again be exposed in the muffle. In about a quarter of an hour we take it out again, pound it over, for the mass is generally clogged, and mix it with about twice its weight of charcoal-dust, after which we continue the roasting for about one-half to a full hour, according as the ore contains a little or much sulphur, vapours of which may be seen rising during the whole of this process.

After this the ore has a reddish, or what is generally called a ferruginous colour, and we now take it from the first crucible, and introduce it into that represented in fig. 4, Plate II., or if not in possession of such, into a Hessian crucible, fig. 5, on the same plate. For this purpose, however, some *black flux* should be provided. It consists of carbonate of potash and lime, and is made by igniting together one part by weight of saltpetre, and two of common tartar. The flux produced should be kept carefully corked to prevent the absorption of hygroscopic water. It is still better to make it only when required for immediate use.

If the ore is poor, one tenth part by weight of oxide of antimony, (antimonious acid,) or of arsenic, (arsenious acid,) or if it is richer, fifteen per-cent. of pure lead* are requisite, as will hereafter be seen to make the particles of copper unite. One of these together with three parts of black flux, one half the weight in borax, and two parts of table salt, must then be added to the roasted ore, though none except a part of the flux are mixed with the mineral now investigating. The salt is merely used to form a crust over the whole. When all have thus been placed in the crucible, they are covered over with a piece of charcoal, cut to match the size of the vessel; after which the cover is put on. We then expose it to a white-heat for about one-half to one full hour, as may be most convenient, either in the draught furnace, fig. 6, Plate I., or in the muffle furnace; in which latter case, we must allow the longest period of time.

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* Some assayers use neither of these three, on the ground that the arsenic, as occasionally even 40 per-cent. may be taken, is very difficult to separate from the copper, and that the antimony may unite with part of the same, forming an antimoniate. They therefore only employ borax and black flux, in about the same proportions, however, as given above. It is hard to say which is best, and it must be left to the discretion and experience of the assayer to act as may be most suitable to his peculiar ores.

The carbon of the flux is intended to reduce the peroxide of copper produced by roasting, while its carbonate of potash unites with the earthy contents of the ore and the oxides of other metals present, such as iron, which would otherwise also be reduced to their metallic state. With these it forms a slag, the borax being added to make it flow easy, and allow the copper to collect in one button.

On cooling, we break open the crucible, and, on removing the slag, extract a spherical piece of impure or alloyed copper, according as other metals may chance to occur in the ore. If any intermediate crust should have formed between the button and the slag, the ore was not properly roasted, a part of the copper not reduced, and consequently the assay is worthless.

In a good assay the slag should be black and vitreous in appearance, never of an earthy texture. If striated or speckled with red, we may know that protoxide of copper is dissolved in it, and again that the whole cannot be productive of an accurate result. Much attention is required during this test, and, as already mentioned under the heads of silver and gold, the final result depends entirely upon the care taken by the assayer. If well managed, however, as here directed, he can hardly fail to be successful.

The button, as remarked above, may

vary in purity. It generally contains some iron, and (since these metals frequently exist in copper ores) lead, bismuth, tin, cobalt, nickel, antimony, and arsenic—the latter two in particular, if they were added in the process of reduction. Thus it very rarely, if ever, happens, that a copper ore is sufficiently pure to require no third process. The less admixtures the alloy contains, the less brittle and the more ductile it is. Nickel particularly tends to harden it.

To remove the foreign metals, the button is put in a piece of paper, with sufficient borax to cover it, (one-fourth to one-third part by weight, rather more than less,) and if no lead occur in the ore, with about from five to ten per-cent. of that metal, which amount, however, should increase up to forty, or even more, if there are many impurities in the alloy. Even if this be not the case, it is always safer, and can never produce any bad effect, to add much.

A crucible of the kind illustrated in fig. 3, is mixed with from one to one and a half parts of pounded glass, which should, however, contain no lead or arsenic, from twenty-five to fifty per-cent. of saltpetre, d fifty per-cent. of borax. Together with ese, it is exposed to a strong melting heat in a clay cr e. On cooling, the button remove the case in the other mode rocedure, common on the conti-

ving hus r ced the copper, it is necessary to purify it, as was also done in the other assay. I must observe, however, that this part of the Cornwall process, again, can only be applied where very little lead is contained in the copper ore.

For this purpose, some *white flux* should be prepared, which is done by igniting together equal parts of saltpetre and tartar. Being as susceptible to the effects of atmospheric moisture as black flux, it requires the same precaution as regards its preservation.

The button of copper alloy is then hammered out flat, to a sheet as thin as it will allow of, without breaking. It is then exposed in a crucible, (fig. 3,) already red-hot, and, as soon as it melts, covered with white flux. Some table-salt, from which the water of crystallization has been removed by heat, is frequently added to give a covering and protect the copper from too immediate contact with the atmosphere, which, together with the heat, would unavoidably create a free oxidation. A considerable ebullition is produced, on the subsiding of which, and when therefore the mass flows quietly, the contents of the crucible are poured into an iron mould, (fig. 6, Plate II.,) greased over beforehand, from which the mass should be removed with a pair of tongs, as soon as sufficiently consolidated, to be dipped in water, which enables us to separate the slag from the copper with greater ease. The purity of the latter is known by its malleability, and by its

ng much at the margin, when
tched on the anvil under the blows of a
hammer. Should this test prove its yet
ncleansed state, it ought again to be sub-
ed to the operation just concluded.
etimes it is necessary to repeat this
ral times.

has already been mentioned, that, par-
larly when not all the copper in an
is contained in the shape of a sulphu-
it is impossible to prevent some of this
metal from escaping into the slag; and therefore, to diminish this loss as much as possible, English assayers collect the slags, both of the reducing and of the purifying processes, and, pounding them up together, mix them with an equal quantity of tartar and some powdered coke.

This mixture is then melted in a Hessian crucible, after being covered over with common salt. The little button produced in this way is of course impure, and requires the same treatment as the larger one, originally procured. This second button is weighed together with the large one, and the result will give very accurately the per-centage of copper in the ore.

XIV.

Assay of Lead Ores by Heat.

THERE is no way of assaying lead ores by heat which gives the full amount of the metal, as it is so easily oxidized by a high temperature. Generally, the loss varies from one-sixth to one-twelfth, or yet more commonly is about a tenth; and for this reason, the result of the assay should afterward be increased by $\frac{1}{10}$, on giving the per-centage of lead.

The assay is performed in the crucible, fig. 4, or in the Hessian one. The part of ore used ought to be about two hundred grains, as lead ores (galena, a sulphuret of most common) are very heavy, therefore are comparatively small in . Three parts, or here six hundred ains, of black flux are mixed up with the wdered ore.

A little piece of very thick wire, or of a nd iron bar, weighing from thirty to y per-cent. of the weight of the lead , is placed on the top, in the crucible.

We then expose the whole to a strong, dy red-heat, for about an hour, in the bellows furnace, fig. 6, Plate I. This is effected by first placing the crucible on the brick, and then making a layer of cold burnt coals, as high as the brick. On this come the live coals, and on them the unburnt ones up to the top of the furnace. When burnt down, we take out the crucibles, and thus obtain a button of pure lead and some slag, besides a remaining portion of the iron.

The latter should be added in excess, to insure the entire absorption of the sulphur.

Galena contains, in hundred parts, 13.45 parts of sulphur to 86.55 of lead, which would require 22.67 parts of metallic iron to form sulphuret of iron, consisting of 37.23 parts of sulphur to 62.77 of iron. If, therefore, two hundred grains of the ore are used, the iron should weigh from 60 to 100 grains. Filings ought never to be used, as they are always covered, to a smaller or greater amount, with oxide. Besides, it is very difficult to get them as free from impurities as wire. Weighed pieces of the latter should be kept in some vial or box for this purpose.

XV.

Assay of Lead Ores by a Wet Process.

THIS method will be found much the more accurate of the two, although it may not often happen that a practical assayer has sufficient time for this proceeding. (See Woehler's Anal. Chem.)

The ore (galena) should be powdered much finer even than in the assay by heat, after which it is moistened with fuming nitric acid, and digested in the sand-bath, by which process it is entirely changed from the sulphuret to the sulphate of lead.

If the mass be diluted with water and filtered, the merest traces only of lead can be found in the solution,—quantities too small to deserve any farther attention. If the ore contain copper, iron, or silver, they will be contained in this filtered solution;

the first are then discovered by ammonia, the latter by muriatic acid.

Should fuming nitric acid not be at hand, and if therefore a weaker kind is used, a mixture of sulphate of lead and sulphur is produced, together with a solution of nitrate of lead. From this latter the metal should be precipitated with sulphuric acid. By heating the dried residue,—after filtering and washing, by pouring water over it while yet on the filter,—sulphur is evaporated and sulphate of lead is retained.

In both cases, the lead produced is a sulphate, and in this shape it should be weighed, and from the result the amount of the former alone may be easily calculated, as will be seen from the sequel.

Sulphate of lead consists, in 100 parts by weight, of

Oxide of lead .	73.56
Sulphuric acid .	26.44
	100.00

and the oxide of lead, again, of

Lead	92.83
Oxygen	7.17

Hence we say, if 100 parts of oxide of lead contain 92.83 of pure lead, then 73.56 of pure lead contain 68.285748 parts; or, in other words, sulphate of lead consists of

Lead	68.285748
Oxygen	5.274252
Sulphuric acid	26.440000
	100.000000

For this assay about twenty grains only need be taken. A smaller amount might make us incapable of finding the real quantity of lead, while a larger one would only give us unnecessary trouble.

XVI.

Assay of Iron Ores by Heat.

ONE part of the ore, about a hundred grains, thoroughly pulverized, is mixed with from thirty to a hundred grains of calcined borax. The quantity of the latter varies according to the purity of the mineral, and increases when it contains many foreign admixtures.

If the ore contains sulphur, it ought first to be roasted, as was the case with the assays of other metals already described.

A Hessian crucible is then prepared with coal, as already directed in the description of those vessels under the head of *Utensils and Implements.* Into the hollow in the centre, the mixture of ore and borax is poured, and on that some charcoal powder; after which the cavity is entirely covered with a piece of charcoal. The crucible is then closed, the number of the assay being marked on the inner surface of the cover. This is then fastened down air-tight with some putty.

The iron ore, after these preliminary arrangements, is to be submitted to a reduction process in the furnace, fig. 6, Plate I., which lasts about three-quarters of an hour.

At the extensive iron-works on the Hartz Mountains in the interior of Germany, a very simple apparatus is used instead of the other furnace, of which, on account of its portability, I here give a description. It consists simply of an open cast-iron pot or jar, measuring about a foot across, and one and a half in height, and having a plate of sheet-iron, perforated with many little holes an inch in diameter, instead of a grate. This leaves a vacant space of about two inches below, to receive the ashes. The latter partition has two openings; one, the door to take out these cinders—the other, to introduce the end of the bellows. Above the iron plate, on which the crucibles are directly placed, without any brick, a coating of fire-clay, an inch thick, extends to the mouth of the jar.

The latter is furthermore supplied with three or four short legs, and a handle on each side.

In this furnace the process lasts about an hour and a quarter.

In both cases, the button produced contains exactly the same impurities, carbon, earths, acids, or other metals, as pig-iron would, if procured from the same ore, and therefore this assay is only to be used for furnaces. For these it entirely suffices; but to ascertain the true amount of pure iron, the wet analysis should be resorted to, the same as with other ores; and it is for this that I shall give directions in the next chapter how to discover or calculate the real per-centage of the pure metal, or to assay the pig-iron produced in the process by heat.

It may not be uninteresting to many, who may honour these pages with their perusal, to become acquainted with a method for obtaining chemically pure iron, as given by Karsten in his famous and voluminous works on this metal. It is described in vol. i., pages 167, 168. He says, to procure chemically pure iron, take the best bar-iron of commerce, e. g. Swedish iron in the shape of small wire; cut it up in short pieces, and then mixing it with about a fourth part by weight of oxide of the same metal, melt it in a Hessian crucible. To cover it, use a compound flux, consisting of pure quartz, pure lime, and equally pure carbonate of potash, in proportions capable of furnishing a glass or slag, not flowing too easily, but of rather a tough consistency.

For the manufacture of an oxide of iron, free from all admixtures of foreign metals, it is best to use small clean wire, oxidizing it by vapours of water.

The button thus produced has a remarkably white colour, a strong metallic lustre, and is more ductile than the best varieties of soft bar-iron. Particularly characteristic, however, is its great specific gravity, amounting to 7.9654, while that of wrought-iron is 7.6 to 7.9, and of cast-iron only from 7.0 to 7.5. The only impurity this metal may be discovered to possess occurs as slight traces of silicium, and therefore it may be considered to be as pure as it possibly can be made, even by a process conducted only upon the rules and principles of wet analysis, and thus in this shape it is utterly unknown to the mere practical metallurgist or smelter.

XVII.

Fuchs's Process for Iron Ores and Iron.

This method, though remarkable for its simplicity, is a very sure one, not only to ascertain the quantity of iron in an ore, but to acquaint us with the peculiar degree of oxidation in which it exists, and also the amount of each oxide, which it is often not only very interesting, but useful to know. Many ores, particularly the magnetic ones, contain both the peroxide and the protoxide, and the only ones to which this process cannot be applied are those containing arsenious acid, not a very common ingredient.

The process discovered or invented by Fuchs is founded on the fact, that chemically pure muriatic acid, when atmospheric air is excluded, is incapable of dissolving any copper; but that, when peroxide of iron is contained in it, a corresponding quantity of that metal becomes soluble, a muriate or chloride of iron and chloride of copper being thus formed.

The ore is dissolved in muriatic acid, and, if necessary, filtered. A small round-bottomed vial should be used. Into the solution a clean weighed strip of copper is placed, and the vessel corked, and covered with a piece of bladder, tied down round the neck until we are ready to boil it. This is best done in a water-bath, and should last until no more copper is received by the acid. The former is then taken out, well washed in water, dried with a towel, and immediately weighed.

The difference in the weight of the copper is all that is required to ascertain the amount of peroxide of iron in the ore, for we need only multiply this by the equivalent of peroxide of iron, which Fuchs takes to be 40, and divide the product by

31.7, the equivalent of copper. The quotient gives the quantity of peroxide contained in the solution or ore.

To know the whole amount of iron in it, we need only weigh off another part, (10—15 grs.,) dissolve it in muriatic acid, and then digest with chlorate of potash, to transform the protoxide into peroxide, after which, copper will decompose the whole. Instead of 40, the equivalent of peroxide of iron, we insert 28, the equivalent of the pure metal, into our calculations. By subtracting the amount of the peroxide from the last result, the amount of the protoxide is found.

The presence of alumina, silica, &c. has no effect on this assay, though the existence of copper in it would represent the ore as poorer than it really is. The latter, however, rarely occurs in common iron or its ores except in mere traces, and, as such, it produces no material difference.

XVIII.

Assay of Sulphurets in Ores.

It is often very necessary to know the quantity of sulphurets contained in ores, to be able to arrange accordingly the processes of smelting them.

To one part of ore, 50 to 100 grains, one part of powdered glass and two of borax are required.

The borax is first mixed with the ore, and when placed in the Hessian crucible, or in the lead and copper one, fig. 4, Plate II., both are covered with the glass. The crucible is then exposed to a bright red-heat, as with copper and lead, and on cooling the button is broken out, which may contain in the shape of sulphurets, copper, lead, iron,

&c., according as these exist in the ore, and it may then be examined for these metals by the means already given in their respective assays.

Table of Analyses of different Clays, from which the most approved Crucibles are made.

Locality, and name of analyzer.	Silica.	Alumina.	Magnesia.	Lime.	Perox. of Iron.	Water and Bitumen.	Carbon.	Total.	To what use applied.
1. From Stourbridge, England, by Berthier.	63.7	20.7	—	—	4.0	10.3	—	98.7	The two first clays, 1 to 3 inclusive, are used chiefly for crucibles in the manufacture of steel in England.
2. Same place by Le Play.	46.1	38.8	—	—	—	12.8	1.5	99.2	
3. From Stammington, England, by Le Play.	42.0	40.9	0.1	1.3	Trace	14.7	—	99.0	
4. From Almerode, Hessia, by Berthier.	46.5	34.9	—	—	3.0	15.2	—	99.6	This is the clay from which the famous Hessian crucibles are made.
5. From Passau, by Leshen.	42.4	57·6	—	—	0.7	—	—	100.7	These two, the first a clay, the second, graphite, are mixed in the proportions of from 3 to 4 of the first to 1 part of the latter, in the manufacture of the well-known Passau graphite crucibles.
6. Graphite from same place, by Berthier.	41.2	14.7	1.0	—	8.2	1.0	33.9	100.0	

Table showing, in Degrees of the Centigrade and Fahrenheit Thermometers, the Amount of Heat necessary to melt various Substances.

			Centigrade.	Fahrenheit.
Platina			2500	4532
Bar Iron			1500–1600	2732–3012
Steel			1300–1400	2372–2552
Cast iron, gray			1200	2192
Do. white			1050	1922
Gold			1100–1250	2012–2282
Silver			1000	1832
Bronze			900	1652
Antimony			450	842
Zinc			360	680
Lead			330	658
Bismuth			260	480
Tin			230	446
Alloys of Tin, (in parts.)	Lead, and (in parts.)	Bismuth. (in parts.)		
1	3	–	289	554
1	1	–	241	464
3	–	1	200	392
3	1	–	186	365
2	–	1	167.7	333.5
1	–	1	142.2	283.8
4	1	5	188·9	246.2
3	2	5	100	212
3	5	8	100	212
1	1	4	94	203
Sulphur			109	230
Mercury			39	38.2

Table of Troy Weights used with Gold, and Silver, and Platina.

24 grains (gr.) make 1 pennyweight (dwt.)
20 pennyweights — 1 ounce (oz.)
12 ounces — 1 pound (lb.)

lb.		oz.		dwt.		gr.
1	=	12	=	240	=	5760
		1	=	20	=	480
				1	=	24

The value of gold is given in carats fine, 24 c. f. being pure.

One pound of gold 24 carats fine contains 5760 grs. of pure gold, as gold of that number of carats fine is unalloyed.

One pound of gold 23 carats fine contains 5520 grs., and so on, and one oz. of gold 20 c. f. has 400 grs.

one dwt. of gold 15 c. f. has 15 grs.

These are given as examples of the manner in which the amount of the pure metal ought to be calculated.

Table of Avoirdupois Weights used with other Metals.

(Tun,) T.		(Hundredweight) cwt.		(Quarter) qr.		(Pound) lb.		(Ounce) oz.		(Dram) dr.
1	=	20	=	80	=	2240	=	35840	=	573440
		1	=	4	=	112	=	1792	=	28672
				1	=	28	=	448	=	7168
						1	=	16	=	256
								1	=	16

A Table of Comparison of Twelve different National

Pound Avoirdupois.	Austrian Pound.	Bavarian Pound.	Saxon (or Soll.) Pound.	Wurtemburg Pound.	Old Cologne Mark.
1	0.80998 9.90847	0.81000 9.90848	0.90720 9.95770	0.96979 9.98668	1.94001 0.28780
1.23460 0.09153	1	1.00002 0.00001	1.12002 0.04923	1.19730 0.07820	2.39514 0.37933
1.23457 0.09152	0.99998 9.99999	1	1.12000 0.04922	1.19728 0.07819	2.39508 0.37932
1.10230 0.04230	0.89284 9.95077	0.89286 9.95078	1	1.06900 0.02898	2.13847 0.33010
1.03115 0.01332	0.83521 9.92180	0.83523 9.92181	0.93546 9.97102	1	2.00044 0.30113
0.51546 9.71220	0.41751 9.62067	0.41752 9.62068	0.46762 9.66990	0.49989 9.69887	1
1.10078 0.04170	0.89160 9.95017	0.89162 9.95618	0.99862 9.99940	1.06752 0.02838	2.13551 0.32950
0.93770 9.97206	0.75952 9.88054	0.75953 9.88055	0.85068 9.92977	0.90937 9.95874	1.81915 0.25987
1.07916 0.03309	0.87410 9.94156	0.87412 9.94157	0.97901 9.99079	1.04656 0.01976	2.09359 0.32089
2.20460 0.34333	1.78568 0.25180	1.78571 0.25181	2.00000 0.30103	2.13800 0.33001	4.27693 0.63113
0.90283 9.95560	0.73127 9.86408	0.73129 9.86409	0.81904 9.91331	0.87555 9.94228	1.75149 0.24341
1.03111 0.01331	0.83518 9.92178	0.83520 9.92179	0.93542 9.97101	0.99996 9.99998	2.00037 0.30111

*Weights, with the Logarithms under each Number.**

Danish and Norwegian Pound.	Swedish Pound.	Old French Pound, (poids du marc.)	French Kilogramme.	Russian Pound.	Prussian Pound, (pud.)
0.90845 9.95880	1.06644 0.02793	0.92664 0.96691	0.45360 9.65667	1.10763 0.04440	0.96982 9.98669
1.12157 0.04983	1.31662 0.11946	1.14404 0.05844	0.56001 9.74820	1.36748 0.13592	1.19735 0.07822
1.12155 0.04982	1.31660 0.11945	1.14401 0.05843	9.56000 9.74819	1.36746 0.13591	1.19732 0.07821
1.00138 0.00060	1.17558 0.07023	1.02144 0.00921	0.50000 9.69897	1.22094 0.08669	1.06904 0.02899
0.93675 9.97162	1.09966 0.04126	0.95551 9.98024	0.46773 9.66999	1.14214 0.05772	1.00004 0.00002
0.46827 9.67050	0.54971 9.74013	0.47765 9.67911	0.23381 9.36887	0.57094 9.75659	0.49991 9.69889
1	1.17391 0.06963	1.02003 0.00861	0.49981 9.69837	1.21925 0.08609	1.06756 0.02839
0·85186 9.93037	1	0.86892 9.93893	0.42534 9.62874	1.03863 0.01646	0.90941 9.95876
0.98037 9.99139	1.15086 0.06102	1	0.48951 9.68976	1.19532 0.07748	1.04660 0.01978
2.00277 0.30163	2.35106 0.37126	2.04288 0.31034	1	2.44188 0.38772	2.13807 0.33002
0.8017 9.91391	0.96281 9.98354	0.83660 9.92252	0.40952 9.61228	1	9.87558 9.94230
0.93672 9.97161	1.09962 0.04124	0.95548 9.98022	0.46771 9.66998	1.14210 0.05770	1

* Taken from Weisbach's Ingenieur.

Fig 1

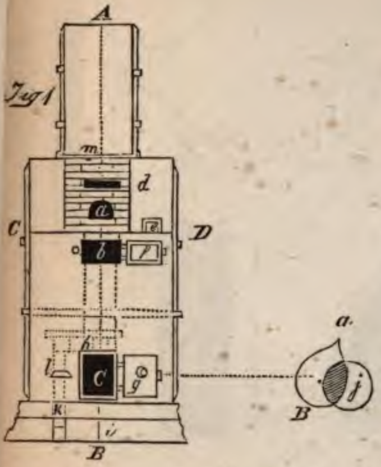


Fig 3

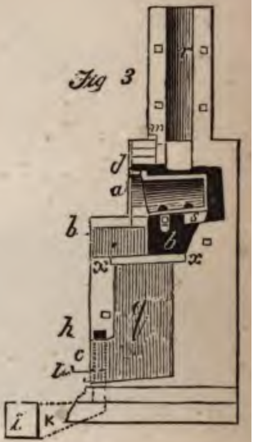
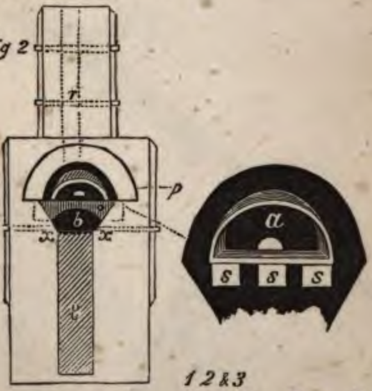


Fig 2



To Figs 1 2 & 3

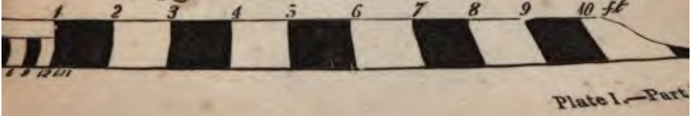


Plate I.—Part

Fig 6

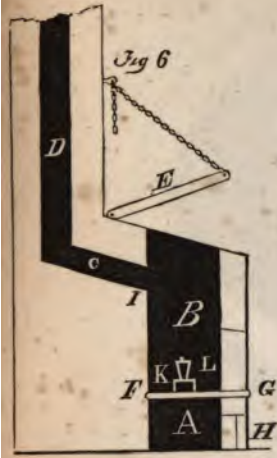


Fig 4

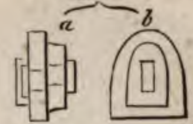


Fig 5

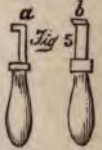


Fig. 8

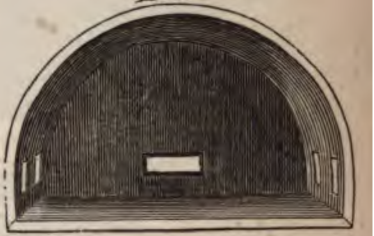


Fig 7

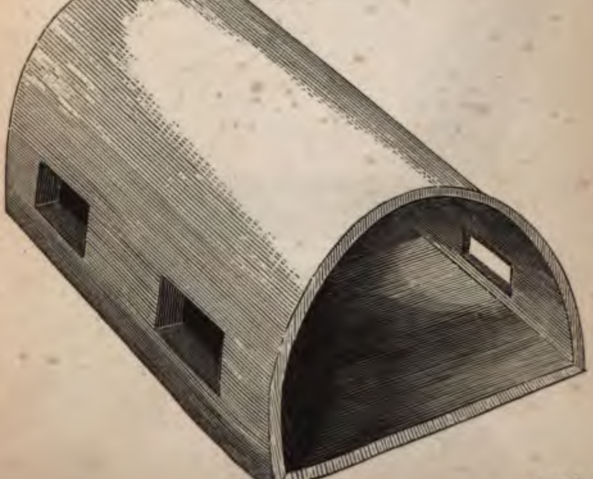


Plate I.—Pa

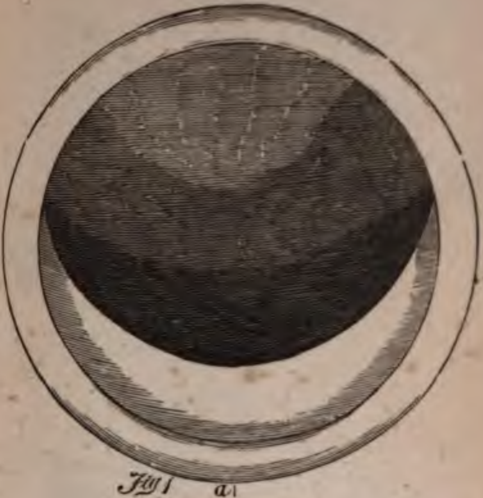


Fig 1

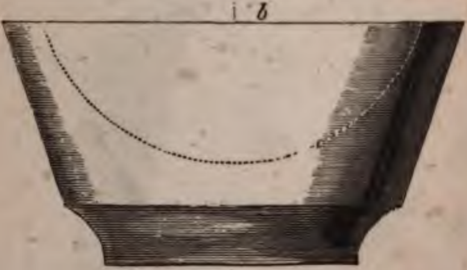


Fig 2

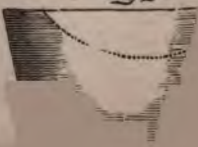


Plate II.–

Fig 3

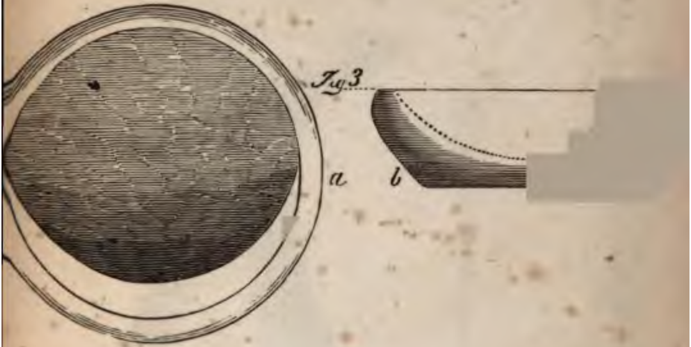


Fig 5

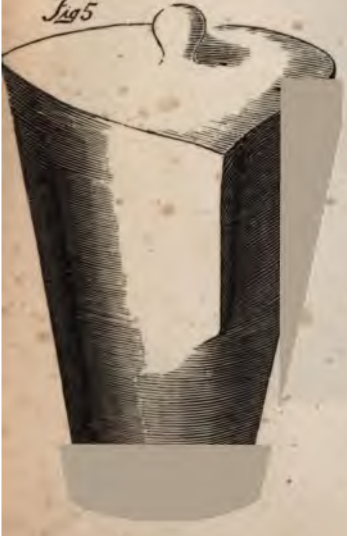


Fig 6

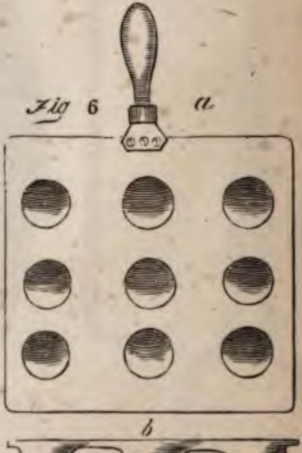


Plate II.—Par

Fig 4

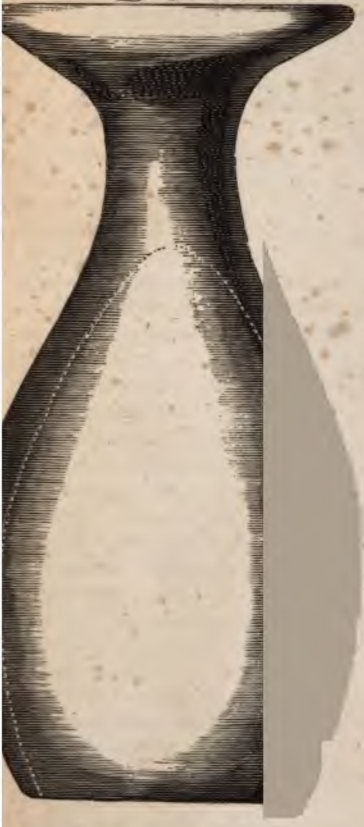


Fig 7

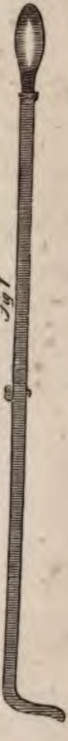


Fig. 8

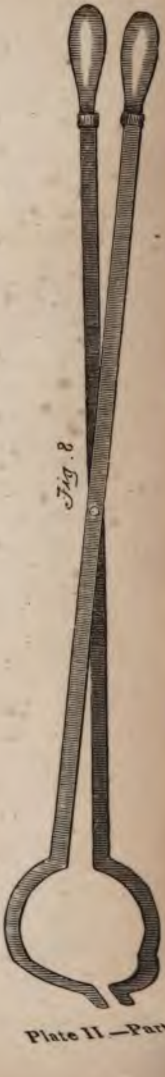


Plate II.—Part II

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